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A Roadmap on Handwritten Gujarati Digit Recognition using Machine Learning

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***Abstract*— One of the major difficulties in the area of pattern recognition and image processing is handwritten character recognition (HCR). For human, this seems to be very easy but for a machine, the task of recognizing handwritings is tedious. In case of machine, first the input needs to be scanned from file, image and real-time device like personal computers, digitizers and tablets. After that, the scanned input is translated in digital text in Handwritten Character Recognition process. There are two ways this can be done: online and offline. In online method, the input is taken at runtime whereas in offline method, the input is a scanned file. The mechanism where the machine understands an image of a handwritten script automatically is known as Offline handwritten character recognition. Various applications of HCR are processing of banks, mail sorting and reading of documents etc. As per the survey carried out, it was seen that the Offline handwriting is relatively challenging, to identify, as different people have different handwriting. As machine learning is a buzz word nowadays and most of the real-time applications are solved easily using the models of machine learning, hence our paper focuses on comparing various techniques of machine learning used to recognize the Gujarati handwriting digits. In Gujarat State, India, Gujarati script used by people to write the Gujarati language.**

Keywords*— *K-nearest neighbor (K-NN), Optical Character Recognition (OCR), Radial Basis Function (RBF), Support Vector System (SVM), Artificial Neural Network (ANN), Handwritten character recognition (HCR).

I. INTRODUCTION

When there were human operators in the 1950s whose role was to translate in electronic format, data from different documents, the development of handwriting recognition systems began, making the process very lengthy and often misunderstood. Text recognition which is done automatically that reduces error by using image processing methods which also make whole recognition process faster and accurate. In the last few years, handwriting recognition has been among the most significant and difficult fields of research in the area of pattern recognition and image processing. It makes an important contribution to advancing the automation process, and in many applications Enhances the man-machine interface. Recognition of digital character is an area of research which includes several diverse methods of solving. Gujarati characters are distinct from other languages since the characters do not have Shirolekha over them. Unlike other languages, digits in Gujarati have different curve forms and different styles of writing. Figure 1 shows various Gujarati digits written by hand.

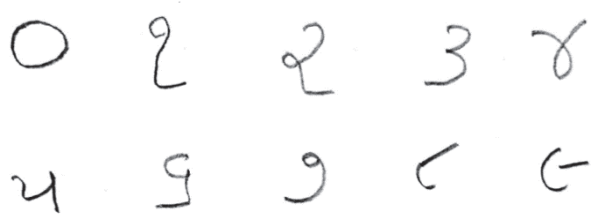

Fig. 1. Handwritten Gujarati Digits

This paper is structured as follows: section II is about related work done in the past. Section III introduces different methods of recognition of Gujarati handwritten digit. Section IV is the comparison of different recognition of Gujarati handwritten digit technique. This paper is concluded in section V.

II. RELATED WORK

Feature Extraction for Handwritten Numeral Based on Stroke Orientation Technique is described in [1] for Devanagari and Gujarati tend to be resilient to different handwriting types and strokes. Fuzzy Template Controlled Recognition of Hindi Handwritten Numbers with Bacterial Foraging [2] Equipped to fuzzy sets on the basis of the modified exponential membership function obtained using the Box method derived from normalized distance characteristics. In paper a neural network is presented for the handwritten recognition of Gujarati digits [3] it is proposed to provide a multi-layered feed forward neural network for the classifying Digits. Gujarati Handwritten Numeral optical character by Classification of Naive Bayes [4] study has achieved a success rate of about 80.5% for Gujarati handwritten digital identification. Handwritten digit identification of Gujarati using Sparse Representation Classifier [5] Demonstrate 80, 33% accuracy. New Function Extraction Method Approach Focused on the Raw and its Skeleton Shape of Handwritten Digits of Gujarati using K-NN Classification [6]. New method of extraction strategy focused on the Raw and its Skeleton Shape for Neural-based handwritten gujarati digits classifier networks [7]. Offline handwritten numeral recognition of Gujarati using strokes of low level [8], On the Gujarati and Devanagari databases, the average test accuracy was 98.46% and 98.65% respectively.

Handwritten online Gujarati Numeral Recognition using Support Vector System [9], The authors obtained 92.60 percent accuracy, 95 percent, and 93.80 percent accuracy for linear , polynomial, RBF kernels, and an average processing time for linear, polynomial, RBF kernels of 0.13 seconds, 0.15 seconds, and 0.18 seconds per stroke.

III. METHODS OF RECOGNITION OF GUJARATI HANDWRITTEN DIGIT

The main component of their recognition is The strokes which result in handwritten numerals. In terms of the characteristics of representing the numerals, point orientations that generate a stroke are here regarded as the main components. The set of features is deemed to be a vector consisting of the repetition count of a set of 16 possible orientations. The accuracy of this set of functions for recognizing handwritten numerals is checked using linear SVM classifier [1]. For extraction of the features it uses the box method. This divides each number into 24 boxes from which are extracted 24 uniform distance features. These 24 attributes allow hike to 24 fuzzy sets of that collect them across various samples. The knowledge base is composed of of 24 fuzzy sets of means and variances that compose the Training dataset reference numbers statistics. Improvements in the means and variances are often taken into account by structural parameters s and t [2].

A feed-back [14], [15] neural propagation network is used to classify the Gujarati numerals. During the pre-processing step, different techniques are used prior to implementing numeral classification. This proposed network's average output is as high as 81.66%, but it's still not up to the mark [3]. Gujarati Four different profiles of digits abstract the characteristics of the Gujarati digits. Skeletonization and binarization is often performed before their classification for the pre-processing of handwritten numerals. Approximately 80.5% of the success rate for Gujarati handwritten digital identification was achieved in this work [4].

Using Sparse Representation Classifier, Handwritten digital Gujarati identification. The classifier assumes that, a linear mixture of samples from trains, a test sample from its native class can be interpreted. Using a dictionary created from the train samples, a test sample may thus be represented. The test sample can be sparse linearly represented effectively determined by l1-minimization in terms of this dictionary and can be used to identify the test sample [5]. In feature extraction stage, the device uses raw form and its skeleton. Contrary to what one would assume, using the proposed method with K-NN does not produce better results compared with using skeletons. The output of each classification system is focused on feature extraction [6]. For Gujarati numerals classification feed forward back propagation neural network approach proposed. Different techniques are used prior to the implementation of numeral classification in the pre-processing stage. The average of this proposed network performance with proposed method is as high as 85.33%, 80.5% with skeleton and 85.33% without skeleton.

The paper's method focuses on the production of a valid size of Gujarati numeral repository with offline handwritten and Using low-level stroke functions, it is readily recognizable. From 140 people 14,000 samples gathered of different educational backgrounds, age groups and tradition of work. A new approach is proposed to remove different features of low-level strokes, two popular Indian scripts, namely Devanagari and Gujarati, to identify handwritten offline numerals, Such as intersection points, endpoints, segments of lines and segments of curves, and a low-level stroke characteristic block-wise histogram. The k-nearest neighbour (k-NN) classifier used to perform baseline analysis, and the outcomes have been further refined, using the statistically sophisticated Radial Basis Function (RBF) Kernel Support Vector Machine (SVM) Classifier [8].

A. Discrete Fourier Transform Fourier Descriptors

Feature vectors are used in [11] Discrete Fourier Transform Fourier Descriptors. Firstly, pre-process the data, after that the thin image boundaries are traced in the direction of the clock. And lastly the necessary steps of Discrete Fourier Transform are performed on it. Complex number is the format of coordinate pairs,

$$z = x + iy \text{ [11]} \quad (1)$$

Where real part is represented by x, imaginary part is represented by y. For ease of computation, we considered only the real part and evaluated the related coefficients that characterize the image's shape. The steps for the mentioned process are as follows:

Step1: isolate the image in to foreground and background image

Step2: To remove the noise apply median filter

Step3: Convert each sample in to 18 X 18 pixel of image

Step4: Thin the picture so that it is one pixel long

Step5: Apply Discrete Fourier for thin image transformation

Step6: Draw out the real portion from the array of generated complex numbers

Step7: Observe and use specific descriptors as feature vectors

It defined 85 dimensional descriptors for Fourier to represent the shape of the images of numerals. The scale and rotation of these invariant Fourier descriptors are invariant.

B. Discrete Cosine Transform

A [11] with a range of cosine-oscillating functions at various frequencies, the Discrete Cosine Transform (DCT) defines a finite series of points of data. DCT is identical to Discrete Fourier Transform. The series can only be recreated from a handful of DCT coefficients. Following are the next steps as:

Step1: isolate the image in to foreground and background image

Step2: To remove the noise apply median filter

Step3: Convert each sample in to 18 X 18 pixel of image

Step4: Thin the picture so that it is one pixel long

Step6: Apply Discrete Cosine transform on thinned image

Step7: Calculate related DCT coefficients

C. K – Nearest Neighbor (KNN)

[12], [13] K – Nearest Neighbor is a univariate identification type. K – Nearest Neighbor is supervised learning algorithm. So that no training is required for algorithm. It predicts the likelihood of unknown pattern posteriori from the frequency of nearest neighbors. It stores the information as a reference and Specifies a minimum distance between the unknown data (Euclidean distance). When new data are entered the models got training. Then after evaluating the plurality of nearest neighbours, assign the class mark to an unknown data set. The K value was extracted from the calculation of the number of neighbours.

D. Support Vector Machine

[17] A binary classifier is the Support Vector Machine (SVM), A dividing line is pursued distance between two groups maximizes this. SVM is focused on mathematical learning theory and optimization of Quadratic programming. Steps listed below for the linear SVM classifier:

$$F(x) = Ị \ i\ xi.x + a\ [17] \qquad (2)$$

Where, xi stands for support vectors, the value of I i and a is calculated by quadratic equation. It is possible to convert this linear classifier to a using the kernel function, the non-linear classifier. The kernel function is replaced by the inner product (xi.x) in order to define the kernel function G as G(x, y) =ĭ (x).ĭ (y).

Support vector machine output varies if the kernel function increase. The kernel function used at Radial basis function, Polynomial, Linear, Sigmoid, etc. Radial basis function and Polynomial Kernel provides batter outcomes for Gujarati handwritten character identification approach.

E. Geometric Method

[11] The geometrical solution is to discover the features of a geometric shape to describe an object by gathering geometric characteristics from images. One of the methods of removing geometric features is Edge Detection. The edge detection categories are the basis for search and zero-crossing. A search-based edge detection system is the Gradient Method. The direction and the magnitude of the gradient are calculated. The gradient directions are considered to vary from being of real interest. So we took the direction of the gradient as a function vector, but we got far less precision. In order to increase accuracy, we have quantified the path spectrum to a smaller number of integer values. For the gradient scope, there are 9 integer values and K= 1 , 2 , 3 ... 9 and we have 900 function vectors for thin images.

IV. COMPARISON OF TECHNIQUES OF GUJARATI HANDWRITTEN RECOGNITION

TABLE I. COMPARISON OF DIFFERENT GUJARATI HANDWRITTEN DIGIT RECOGNITION TECHNIQUES

Techniques	Pre-Processing	Feature Extractor	Classifier
Stroke Orientation Estimation Technique [1]	Binarization, Thinning	Stroke based	Linear SVM
Neural network [3]	Digitization, Contrast Correction, Resizing, Thinning, Rotate Training set	Profiles	Artificial neural network [ANN]
Naive Bayes [4]	Resizing, Binarization, Skeletonization	Box-approach	Naive Bayes
Sparse Representation Classifier [5]	Resizing, Binarization, Skeletonization	Box-approach	Sparse Representation Classifier (SRC)
Raw Form and his Skeleton & K-NN Classifier [6]	Resizing, Binarization, Skeletonization	The character's raw form and his skeleton	k-nearest neighbor (k-NN)
Raw Form and his Skeleton & Neural networks classifier [7]	Resizing, Binarization, Skeletonization	The character's raw form and his skeleton	Neural network
Low-level strokes [8]	Noise removal, Resizing, Thinning	Low-level stroke features	k-nearest neighbour (k-NN) , statistically sophisticated Radial Basis Function (RBF) Kernel Support Vector Machine (SVM) Classifier
Support Vector Machine [9]	-	Stroke based	Help Vector Machine (SVM) with the kernels of linear , polynomial, and radial base functions
Wavelet Features Extraction [16]	-	General regression neural network	K Nearest Neighbor classifier
wavelet multi-resolution analysis [16]	Non- linear normalization	Optical character recognition	Support Vector Machines
Principal Component Analysis [16]	-	-	Support Vector Machines with 2-stage classifier
Template Matching [16]	-	-	Fringe distance classifier
Correlation Analysis [15]	-	-	Cross Correlation Coefficient classifier
Multiple kernels Learning [15]	-	Multiple kernels Learning (MKL)	Multiclass classification with K Nearest Neighbor

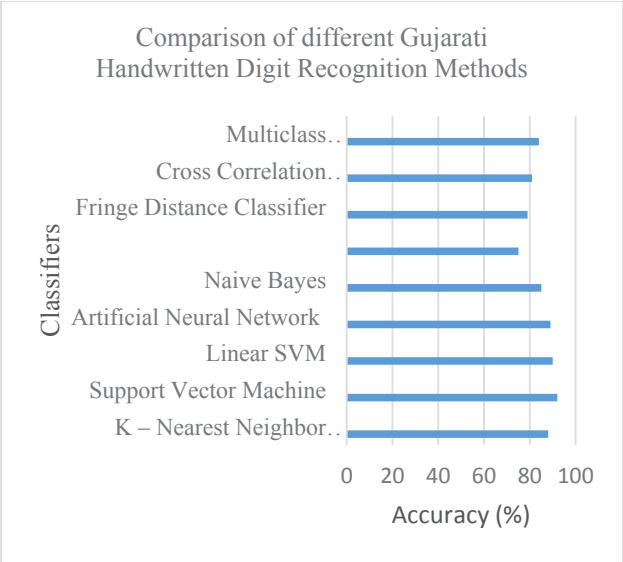

Fig. 2. Comparison of different Gujarati Handwritten Digit Recognition Methods

As shown in Table 1 & Figure 2, different techniques and classifier for Gujarati handwritten digit recognition are compared using accuracy level of recognition . Comparison is based on different technique used in pre-processing, Feature Extractor and classifier used for recognition of Gujarati Handwritten Digit.

V. CONCLUSION

Developing a good OCR program lets people avoid entering important documents manually while inserting them into online repositories. For Indian scripts, several researchers have achieved a strong recognition rate, but that rate is for an individual character. It is very complex to classify characters with various modifiers and specially linked or joint characters. No such commercially accessible Gujarati script OCR software permits hundred percent accuracy of searchable digitized printed or written text. The reason behind this is unique writing style and the handwriting of the individual. It is needless to assume, because of stumbling writing or laziness that specimens of the same author on a specific character vary in different situations. In addition to it, the handwriting of different people differs as it affects Many factors, such as the quality of the paper obtained, the printing materials used, writing education, and other factors such as tension, encouragement, and even the intent of handwriting. In the field of Gujarati character recognition, the researchers have been working hard from the past two decades. Despite all, even though sophisticated computer scanners are available, PDAs the transformation of the document into its digitized form remains an open problem. In our review, it was seen that the performance of the algorithms vary depending on the dataset used. The dataset used in one technique may not be used in other technique. So, in future work, considering same dataset, it can be implemented using all the techniques and then a good comparison table can be prepared wherein it can be concluded that which technique is suitable for which dataset.

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